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## Comment on “Conductance Fluctuations in Mesoscopic Normal-Metal/Superconductor Samples”

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# Comment on “Conductance Fluctuations in Mesoscopic Normal-Metal/Superconductor Samples”

Recently, Hecker *et al.* [1] experimentally studied magnetoconductance fluctuations in a mesoscopic Au wire connected to a superconducting Nb contact. They compared the rms magnitude of these conductance fluctuations in the superconducting state [ $\text{rms}(G_{\text{NS}})$ ] to that in the normal state [ $\text{rms}(G_{\text{N}})$ ] by increasing the magnetic field above the critical field of 2.5 T. It was reported that  $\text{rms}(G_{\text{NS}})$  was about  $2.8 \pm 0.4$  times larger than  $\text{rms}(G_{\text{N}})$ , which should confirm the theoretical predicted enhancement factor of  $2\sqrt{2} \approx 2.8$ .

In this Comment, we show that their claim is not justified. Although not explicitly mentioned in Ref. [1], we have to assume that the  $\text{rms}(G)$  was calculated according to  $\text{rms}(G) = \text{rms}(R)/R^2$ , where  $\text{rms}(R)$  denotes the rms magnitude of the measured resistance fluctuations and  $R$  the total measured resistance. The point we want to make is that the authors did not take into account the presence of an incoherent series resistance  $R_{\text{series}}$  from the contacts, which is different when the Nb is in the superconducting or normal state. Since the measured  $\text{rms}(R)$  originates only from the phase-coherent part of the disordered conductor, with resistance  $R_{\varphi}$ , the correct procedure is to calculate  $\text{rms}(G)$  according to  $\text{rms}(G) = \text{rms}(R)/R_{\varphi}^2 = \text{rms}(R)/(R - R_{\text{series}})^2$ . As shown below, when we correct for the presence of this series resistance, we find that  $\text{rms}(G_{\text{NS}})$  is *not* significantly larger than  $\text{rms}(G_{\text{N}})$ .

Their device consists of a narrow Au wire ( $\text{Au}^w$ , length  $L = 1.0 \mu\text{m}$ , width  $W = 0.13 \mu\text{m}$ ) connected at its ends to a macroscopic Nb and Au contact ( $\text{Nb}^c$  or  $\text{Au}^c$ ) via a rectangular shaped contact ( $\text{Nb}^r$  or  $\text{Au}^r$ ,  $L = 0.8 \mu\text{m}$ ,  $W = 1.6 \mu\text{m}$ ). The total resistance is the sum of these five contributions:  $R = R_{\text{Nb}}^c + R_{\text{Nb}}^r + R_{\text{Au}}^w + R_{\text{Au}}^r + R_{\text{Au}}^c$ , where  $R_{\text{Nb}}^c + R_{\text{Nb}}^r$  are zero in the superconducting state.

Since the series resistances of the Au contact ( $R_{\text{Au}}^c + R_{\text{Au}}^r \approx 1.2R_{\square}^{\text{Au}} \approx 1.1 \Omega$ ) are small compared to phase-coherent resistance of the Au wire ( $10.5 \Omega$ ), we will correct only for the series resistances of the Nb contact ( $R_{\text{Nb}}^c + R_{\text{Nb}}^r \approx 1.2R_{\square}^{\text{Nb}} \approx 4.8 \Omega$ ). This series resistance is present only in the normal state and is exactly equal to the increase in resistance when the magnetic field exceeds  $B_c$  (see Fig. 1(a), in Ref. [1]). We note that not only the macroscopic Nb contact is regarded to be incoherent but the rectangular shaped Nb contact as well. Namely, the phase-breaking length  $L_{\varphi} \equiv \sqrt{D\tau_{\varphi}}$  for Nb is expected to be reduced compared to  $L_{\varphi} \approx 0.6 \mu\text{m}$

TABLE I. The measured resistance  $R_{\text{NS}}$  and uncorrected conductance fluctuations  $\text{rms}(G_{\text{NS}})$  in the superconducting state at  $T = 50 \text{ mK}$  and  $B = 1 \text{ T}$ , and the measured resistance  $R_{\text{N}}$  and the *corrected* conductance fluctuations  $\text{rms}(G_{\text{N}})$  in the normal state at  $T = 50 \text{ mK}$  and  $B = 4 \text{ T}$ .

	Sample 1	Sample 2
$R_{\text{NS}} (\Omega)$	11.60	9.72
$R_{\text{N}} (\Omega)$	15.87	14.34
$\text{rms}(G_{\text{NS}}) (e^2/h)$	$0.16 \pm 0.02$	$0.14 \pm 0.02$
$\text{rms}(G_{\text{N}}) (e^2/h)$	$0.109 \pm 0.006$	$0.109 \pm 0.009$
$\text{rms}(G_{\text{NS}})/\text{rms}(G_{\text{N}})$	$1.5 \pm 0.2$	$1.3 \pm 0.2$

for Au by  $\sqrt{D_{\text{Au}}/D_{\text{Nb}}} \approx 2.5$ , which implies that the resistance fluctuations from this Nb rectangle are strongly suppressed due to ensemble averaging as well.

In Table I we have reproduced the measured (average) resistance of the two studied samples in the normal state and in the superconducting state. We did not correct  $\text{rms}(G_{\text{NS}})$  [2]. The  $\text{rms}(G_{\text{N}})$  has been corrected as described above. As a result, the  $\text{rms}(G_{\text{N}})$  are a factor of  $(R_{\text{N}}/R_{\text{NS}})^2 \approx 2$  larger than reported in Ref. [1] and, consequently, the ratio  $\text{rms}(G_{\text{NS}})/\text{rms}(G_{\text{N}})$  becomes about  $1.4 \pm 0.2$ . We doubt, however, that the remaining difference from 1 is significant, since the statistical error could well be larger than 0.2 due to the fact that only a few large fluctuations determine  $\text{rms}(G_{\text{NS}})$  (see Figs. (1b) and 2, in Ref. [1]).

In conclusion, we have argued that the measured  $\text{rms}(G_{\text{NS}})$  is not significantly enhanced compared to  $\text{rms}(G_{\text{N}})$ , and it remains an experimental challenge to observe the predicted enhancement factor of  $2\sqrt{2}$ .

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- [1] K. Hecker, H. Hegger, A. Altland, and K. Fiegle, Phys. Rev. Lett. **79**, 1547 (1997).
- [2] The reported values for  $\text{rms}(G_{\text{NS}})$  are considerably smaller than the rms magnitude of the sample-specific conductance fluctuations of about  $\text{rms}(G_{\text{NS}}) \approx 1.0e^2/h$  observed in both a cross-shaped and a T-shaped two-dimensional electron gas coupled to superconductors. S. G. den Hartog *et al.*, Phys. Rev. Lett. **77**, 4954 (1996); S. G. den Hartog *et al.*, *ibid.* **76**, 4592 (1996). A comparison with the normal state values was not made in these experiments.